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FROM 'APPRENTICESHIP' TO 'TRAINING': AN EMPIRICAL ENQUIRY INTO THE PREPARATION OF SCIENTISTS IN SPANISH ACADEMIC SCIENCE

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Abstract:

When a person embarks upon a professional scientific career, what features define their training process? How is this process related to scientific practice and, in general, its development within the organisational setting of the R&D system? The changes affecting contemporary science since the late 20th century mirror several characteristic features of the scientific profession, namely the working conditions of scientists, how professional careers are organised, the way in which scientific work is assessed and how scientists are trained in the academic world. Researchers in academic science today are faced with far-reaching reforms which are currently taking place in universities and official research centres; changes which respond to the growing complexity in the organisation of scientific work and the pressures of science and university policy. Insofar as traditional researchers were considered academic workers, scientists in the public sector must now satisfy the organisational requirements of disciplines and institutions alike. This changing situation has affected the way in which new scientists are recruited and trained and the rôle played by both the doctoral thesis and the young researcher in scientific groups. These changes have also had repercussions for new researchers in their process of socialisation , deepening the trends of social change in academic science, especially in those institutions and R&D systems that are more firmly anchored in the traditional organisational patterns of academia. This paper examines the significance of these issues and illustrates empirically how young researchers are trained in Spanish academic institutions. Through surveys of grant recipients and researchers, discussion groups and in-depth interviews, the training strategies carried out in a range of scientific disciplines and the organisational contexts of Spanish science are examined along with the specific ramifications this situation has for the social restructuring of science in Spain.

Research training in changing R&D systems

In the last half of the 20th century, the organisation of science has experienced profound changes; two of which have especially far-reaching consequences for research training: the restructuring of traditional scientific organisations, particularly in universities; and the increasingly rationalistic nature of science policy-making.

Throughout the history of science, both the organisation of academia and the recruitment and training of new academics reflected the peculiar social structure of the traditional university. The freedom of departmental chairs to make decisions, self-regulation, and a certain degree of independence from public bodies were the principal features that differentiated universities from other public bureaucracies; features that have allowed them to persist as genuine corporations to this day [Ben-David 1977]. This social subsystem was reinforced by the common culture of academic independence and by the specialised nature of the work carried out by professors and researchers, making external control of the work process both difficult and unfruitful.

The organisational pattern described above provides the setting for the main characteristics of research training in this context. First, training was defined by the prevailing practices in academic science, that is to say, by science conducted in official institutions of higher education which were characterised by a high level of self-regulation and freedom with regard to external influence or demands. It is not surprising, then, that this way of doing science meant that new academics were socialised in the shared values of science, namely the freedom to choose their subject matter and to do research, together with a deep personal commitment to developing knowledge [Ben-David, 1972; Leggon, 1996]. Second, this type of training took place behind university walls and was reserved for an elite (those who aspired to academia) and was generally linked to the initial stages of a postgraduate degree where research and teaching went hand-in-hand. Training depended upon direct interaction with an academic supervisor or other members of the academic community and shared common features with the classic guild-like relationship between master and apprentice. It was, therefore, a loosely structured process in the form of courses and classes which were often akin to doing research. After a given period of time, the apprenticeship usually culminated in the writing of a thesis whereby the candidate gained official recognition as a new member amongst a group of equals.

Although the term ‘traditional’ has been used here to refer to this type of training, that is not to say that it is no longer in force. Indeed, this model continues to be practised in many European research systems and, in fact, may be inherent to the professional ideology of academics in all research systems. In recent decades, however, important events have taken place which have contributed to a reshaping of the university system and their research training models. Since the 1950s, four major trends can be seen in a number of countries which have radically reformed their universities: i) greater access to universities by a larger percentage of the population, ii) the expansion of the labour market for highly qualified personnel, iii) the development of different disciplines within the sciences, and iv) the growing rôle of governments in supporting and monitoring university institutions [Clark, 1995]. These trends have, to a large degree, brought about changes in the way research training is structured. The elitist university that once prepared only a small section of the younger population for professional and management sectors, has practically ceased to exist in the western world, especially in public or state-run institutions.

Hence, the traditional system of training in academia is being replaced by one which attempts to accommodate the different training demands of a growing number of students. This new standard includes more structured training, a change in the rôle of the doctoral thesis, and the use of different management tools. It is a situation, however, which poses several problems deriving from differences in the research capabilities of the universities, the division of teaching and research duties, the difficulties faced by faculty members to dedicate time to highly scientific postgraduate studies, and the absence of supervision and evaluation mechanisms which can be employed in a variety of situations.

Another important change that has affected the scientific institution is that public science policy increasingly views science as just another public resource that must be profitable and managed according to what is known as 'enterprise culture' [Keat and Abercrombie, 1991] applied to the public sector. This phenomenon reached its height in the 1980s with the emergence of the so-called Steady State [Ziman, 1987[a]] through the rigorous selection of research to be financed, the introduction of market-oriented management tools, and the adoption of evaluation procedures, all within a framework of limited resources.

In terms of the social organisation of science, these changes have given rise to an alternative framework in which organisational criteria respond to the applicability and usefulness of knowledge and where the audience is composed of diverse economic, social and political actors who are not scientists and where rewards are not distributed only on the basis of recognition.[1] Aside from the division of science into two traditional spheres - academic science and industrial science - the most notable trend today is the diversification of academic scientific institutions into two directions: a classic academic sphere and a sphere that incorporates management tools appropriate to non-academic science. Additionally, certain organisations are split into groups or units along these same lines, as is the work of the scientists themselves.

In the framework described above, the planning and regulation of research personnel and the training of new scientists, in particular, is no longer the exclusive domain of the university, but has become one of the fundamental components of national research systems and the policies that concern them. Until recent years, research training was rarely considered to be of importance to science policy and university management, but was instead the unplanned result of more general initiatives of higher education and science policy. A detailed analysis of the actions taken in this field, therefore, does not exist as it is an issue which has not merited the implementation of specific policies, nor has it been of interest to science policy researchers. Nonetheless, it is useful to contextualise the problem in relation to the measures taken in the sphere of R&D policy since, in our opinion, it is precisely these measures that have determined the changes occurring in the way researchers are trained today.

Measures taken in the field of human resources have largely depended upon the predominate paradigms in the organisation of science[2] and have acted upon them in accordance with the objectives pursued by science policy. First, in policies centred on 'big science' [Polanyi, 1962] (1945-1960), decisions concerning the reproduction of the scientific community were left up to the researchers themselves. Policy in this field consisted of distributing funds to train new scientists in areas which were considered to be of greater interest. Insofar as science was viewed as an engine of progress, funding for human resources was understood to be just one resource among many at the disposal of the scientific community. The second paradigm (1960-1980) consisted of adapting science policy to national problems that were considered relevant and priorities were defined accordingly. Decisions were taken, above all, in areas and fields where new researchers needed to be trained and for those specialities considered to be scientifically significant. Management was limited and supervision amounted to little more than measuring certain outputs such as the number of researchers per field and the production of doctoral theses. It was not until the third paradigm came into effect (1980 onwards) – where the planning and management of science depended on the profitability of public investment - when human resource management policy, including training, merited greater attention. At this time, the optimisation of human resource funding took on new meaning, namely in terms of the amount of time spent on training, the usefulness of human resources in R&D and the interrelation of the different parts of the system (e.g. the balance between academic and industrial research and the exchange of personnel between the two).

However, despite the fact that the human factor is key to any research system, the rationalising mechanisms of science policy have not been implemented in the same way in human resources as they have been in other parts of the system for the reasons mentioned above: the principles of freedom and self-regulation that predominate in the scientific community - which in some R&D systems are endorsed by the organisational system of public science - and the highly specialised content of the work done by scientists, making it difficult for outside bodies to program and supervise research.

Nevertheless, following the changes that took place within academic science institutions, research conditions are being redefined. The new requirements imposed upon academic science have introduced certain criteria which are foreign to the traditional ideological *ethos* of science and are transforming it into a cultural form through the construction of a set of distinct cognitive and social norms. In short, many R&D systems are moving away from academia-oriented research training models towards a more professional system in accordance with scientific practice. In some cases this is the direct result of science policy requirements, while in others it is the consequence of the internal restructuring of scientific specialities.

This change, then, consists of a move away from the apprenticeship pattern towards the training[3] of young researchers to acquire scientific knowledge. Thus the master-disciple context where training is conducted in an informal manner within the discipline and is subject to few external controls has given way to a context to train researchers as scientific workers and to provide them with useful skills to do research in a given discipline, and where both teaching and evaluation procedures are specific, regulated and supervised.

Research training in Spanish academic science.

A similar trend can also be seen in Spanish science, although the measures concerning human resources have their own particular characteristics and decisions are based upon science rather than university policy or the reorganisation of the universities themselves. Research training policy under the Spanish R&D system can best be understood if we take into account that the predominant form of reproduction of scientific groups in academia was normally ‘spontaneous’ in terms of its planning and ‘traditional’ in terms of its *modus operandi* like a great deal of Spanish research before the implementation of modern research policy in the 1980s.

The far-reaching objectives and actions of new science policy have attempted to rectify these existing shortcomings in Spain. Initially, the National Spanish R&D Plan - the main tool used by The State to plan and finance science - was explicitly aimed at fomenting academic science. Its principal goals included the co-ordination, growth and profitability of the system through the distribution of projects, infrastructures, and research grants.[4] This gave rise to the gradual introduction of mechanisms for programming, supervising and evaluating activities. The first phases of science policy - from 1986 to 1995 - were a transitional stage which laid the foundations for more consolidated policy in accordance with international standards to foster measures in the Spanish scientific community which were appropriate to the cycle of credibility in science.[5] Advances in science policy - following the III National R&D Plan in 1995 and especially after the reorganisation brought about by the latest National Plan in 2000- are characterised by their attempts to cross the boundaries of academic science and promote research in collaboration with other sectors. This new approach means that R&D policy is carried out in target areas where profitability and market-oriented strategies determine research objectives and funding.

Whereas in the 1980s and 1990s the main objective was to pave the way for the development of science in a clearly obsolete framework, today the objectives of research are explicitly linked to the socio-economic sector. The recent evolution of science policy has come to recognise the importance of research for economic development and the fact that technological innovations increasingly depend on interaction between the different parts of the system. In short, the development of science policy has meant that the predominant paradigm in the field of science has been reinforced with the objective of pursuing greater rationalisation, socio-economic usefulness and a framework that allows for the development of a new model of social organisation. Hence, there is a clear trend towards applied research, and as a result of greater investments in infrastructures and research funding, research is moving away from the practices of traditional academic research which, in turn, has important social consequences for the organisation of scientific institutions in Spain.

Training policy has also evolved significantly since the period prior to the 1980s, especially with regard to the minor rôle played by universities in research, its capacity for self-regulation and the existence of a predominant training practice based on the interaction between master and apprentice which was linked to doctoral studies and entry-level teaching positions at universities with a total lack of planning mechanisms. Human resource policy has meant a break with the traditional system and model of training which was regulated through doctoral programmes.[6] The possibility of professionalising access to science, the selective assignment of grant holders to research groups and the existence of a certain degree of planning in terms of numbers of researchers are all features that characterise the general trend of change that has been increasingly fomented in the recent evolution of this policy: the distribution of grants is ever more selective with respect to groups and specific research projects and scientists are given increasingly less freedom to train young researchers. Science policy, implemented by both State and regional authorities, is thus witnessing a change in the way human resources are understood: no longer are they viewed as just one more resource available to scientific communities nor is research training structured around academic degrees.

Nevertheless, in the current situation of science in Spain, science policy has focused mainly on planning and funding research within a framework of scientific institutions where individual and groups of scientists continue to be the essential actors for the reproduction of scientific professionals. Unquestionably, this tension influences the way in which research training is done in academia, where training continues to depend on decisions made by the scientific community as it members have the freedom to decide whether to supervise doctoral theses and grants or not. It also depends on the actions that they take in the area of training, as well as in the development of scientific work done by groups of researchers, since there is a lack of guidelines in training practices apart from a demand for relevant topics, well funded projects and final reviews made at the end of scholarship periods.

Toward an analytical framework for research training.

The analysis outlined thus far illustrates the emergence of two complex and opposing organisational models within the orbit of public science; models which can be found in the majority of national R&D systems having different research training practices. Figure 1 is a typology of these two models and includes features, which although difficult to find in a pure state, respond to situations with a distinct rationale in terms of the way they operate.

FIGURE 1: RESEARCH TRAINING MODELS

	MODEL I 'Apprenticeship'	MODEL II 'Training'
DECISION-MAKING BODIES	Scientific Communities	Science policy-making agencies
DISTRIBUTION OF RESOURCES	Reproduction	Prospective, planning
OBJECTIVES	Production of Knowledge	Skills acquisition
TYPE OF PREPARATION	Autonomous, Master-disciple relationship	Integrated, Collective set of activities
ATTITUDES PURSUED	Creativity, Originality	Qualification, Relevance
EVALUATION	Periodical supervision, Thesis	Regular supervision, Skills assessment
ORIENTATION OF RESEARCH CAREER	Academic career, Development of a discipline	Exchange, Transfer of knowledge

As shown above, the decisions as to exactly what type of human resources need to be trained and how funds should be distributed, follow very distinct criteria. In Model I, decisions are made by self-regulating scientific communities, that is, by scientific groups which control their own reproduction. In Model II, control is in the hands of management, that is, experts commissioned by political bodies to make decisions according to set criteria for the programmed distribution of resources. The definition of objectives also follows a different pattern in each model. In the first, the fundamental aim is to produce personnel whose principal task is to develop knowledge which may or may not be of interest to other sectors of society, while the main goal of the second model is to produce human resources with relevant skills for society at large or for a target sector that, in the future, will be able to return the investment.

With regard to training practices, the apprenticeship model essentially hinges upon classical methods of learning while the scientific worker model follows standard research training procedures aimed at teaching specific skills. Although it is true that not all scientific work is purely technical and necessitates tacit instrumental knowledge and intellectual capacities that cannot be acquired through a regulated process, the difference lies in the importance given to the training process and the tools used to carry it out. Thus the first model is chiefly defined by interaction with one or several members of the scientific community. In the second, the tools become objectified in the form of training activities which are developed around a research operative, generally a well-funded project.

Consequently, different modes of supervision are aimed at achieving distinct objectives. Whereas in the first model supervision is basically restricted to completing a thesis, the second model is more structured and frequently includes periodical evaluations, supervision of the research underway and sometimes a final assessment of the skills acquired. Creativity and originality of research are qualities which are pursued and fostered in the first model, while the relevance of acquired knowledge and the skills needed to carry out specific research predominate in the second. Finally, the orientation of a research career differs between the two models. Model I is predominantly oriented towards an academic career based on the development of a discipline. Model II is more likely to be aimed at other occupational sectors and involves a greater exchange of knowledge between them. This second type is especially relevant for public authorities who seek to transfer knowledge considered strategic to extra-academic sectors.

The two models described here are quite abstract and certainly do not do justice to the wealth and diversity of the specific training procedures used by and for scientists, especially if we consider the large number of scientific specialities. Nonetheless, the outline above is useful in describing the predominant practices in different research systems and above all, to demonstrate a trend observed in academia: the move away from Model I which corresponds to traditional training practices towards Model II which is a result of the changes occurring in the scientific world, a transition which is taking place at different rates depending on both political and organisational contexts .

Within the framework of scientific organisations, then, this transition depends on the internal hierarchy of the organisation, as well as the economic and organisational needs of the research projects underway. The predominance of one or another model in national R&D systems is determined by the development of science policy in the terms mentioned above and the move away from a simple to a complex model. Clearly, the general trend towards a science with a complex organisational structure calls for greater supervision and planning in the training of new scientists through a system that differs from traditional academic science where research is conducted in small groups or by individual researchers.

Methodology

The data used for this study was obtained from a research project designed to assess science training policy under the Spanish R&D system.[7] Based upon this data, the hypothesis proposed here is examined from a twofold perspective as follows:

i) The incorporation into science of research trainees. The characteristics of the work carried out by post-graduates in different organisations who received grants from the National R&D Plan were studied using a survey (n=1268) and group discussions as the data source.[8]

ii) Researchers in Spanish academia. The strategies of professors and researchers with experience in training scientists, especially with regard to selection criteria and the organisation of scientific activity were studied. This data source included a second survey (n=1575)[9] and in-depth interviews.

Both samples include a variety of institutions and disciplines in Spanish academic science. The respondents are comprised of post-graduates and professors at public universities and official centres, principally the CSIC (Spanish Research Council). All scientific disciplines, including the social sciences and humanities as well as natural, experimental and technological sciences were represented in the study population. Data analysis was performed in order to examine the differences and similarities which exist within these institutions and disciplines.

The analysis strategy used to test the general hypothesis of this paper consisted of a combination of several multivariate statistical procedures as follows:

i) First, groups of training-related variables were selected from both surveys. With these sets of variables an exploratory analysis was carried out in order to examine the interrelation of values and the existence of common variation criteria that could be interpreted as subjacent dimensions. Data reduction techniques have been used by means of optimal scale procedures that permit the use of data with distinct measurement levels and their reduction into dimensions.

ii) Once the dimensions that reflected the types of training were established, a clustering procedure was used to classify the members of both samples into significant groups in relation to the established models. Cluster analysis was performed, using the resulting dimensions from the reduction analysis as variables.[10]

iii) Lastly, the types found were characterised, allowing us to observe the training modes in the different areas of Spanish science and study the empirical scope of the initial hypothesis.

Data analysis sequence was intended as a first step towards constructing a more formalised operative procedure, bearing in mind that the available data was not designed to test a specific hypothesis, but instead to evaluate how the training systems work. For this reason, the variables used in this study correspond to the dimensions shown in Figure 1 which are more related to the general content of the training process and the supervision carried out during scholarship period. The results obtained from the analysis can contribute to identify a larger and more detailed set of variables that could be adapted to each of the dimensions of the model described above.

Becoming a scientist

Bearing in mind that the chief focus of training policy in Spain since the 1980s has been to produce human resources in target areas, grant funding has centred upon the training capabilities of supervisors and the centres where doctoral candidates do their research, although the aim of a large number of grants has been to train a pool of university teachers in a variety of fields which were growing steadily in Spanish universities. Thus, the criteria for funding grants is quite heterogeneous in terms of the characteristics of the supervisors and centres who are granted ample freedom to do research. Nonetheless, in order to receive a grant, candidates must be accepted by a department or research institute under the supervision of a researcher who has previously endorsed their candidature.

But exactly what *does* training involve? Given that the participants in the study come from a large variety of scientific disciplines, I have examined the most common organisational practices in relation to the type of work trainees do, the supervision and pace of the work conducted by them and the rôle they play within the research group. The results are shown in Table 1. The work conducted by the majority of post-grads can be divided into two categories: exclusive dedication to tasks related to the doctoral thesis (47.7%), and work on a research project in a department or institute in order to do a thesis based on research findings (47.2%). Very few of those surveyed perform work which is not aimed at completing their thesis. Of those surveyed, 16.5% responded that they 'often' participated in tasks which were not related to their thesis (i.e. other research projects in the centre and publications in collaboration with the supervisor), while 13.7% stated that they did this type of work 'very often'. 43.4% of the participants stated that supervision was based on publications, and the majority (73.5%) said that they spent more than 70% of their time at the centre. Finally, 46.9% of the post-graduates also perform teaching duties.

Table 1: Training features of postgraduates

The analysis here attempts to demonstrate that certain practices are interrelated in a logical manner and involve specific research activities. Graph 1 shows the results of the two dimensional analysis with two groups of variables for each dimension (see Table 5 for component loadings). The first dimension includes the variables 'existence of publication-based supervision', 'collaboration with the supervisor in publications,' and, to a lesser degree, 'main tasks undertaken' and is interpreted as 'modes of association to work.' These, in turn, are polarised into two extremes: those who participate in projects distinct from their own, collaborate with the supervisor in publications and where supervision is based mainly on publications, while the opposite can be found at the other extreme. The second dimension is composed of the following variables: 'main tasks performed during the grant period', 'teaching duties', 'collaboration in other research', and 'amount of time spent at workplace.' The second dimension can be interpreted as the nucleus of principal tasks which is defined by the type of task undertaken. In this case it can be seen that respondents who said that they spent less time at the workplace (50% or less) or regularly performed teaching duties are clustered around the category 'exclusive dedication to the doctoral thesis.' The opposite response - those who combine thesis work with work on a project - is located at the other extreme of the dimension near those who responded that they did not perform teaching duties or indicated that they spent a greater amount of time at the centre. On the other hand, there exist certain logical interrelations between the two dimensions. The nucleus of more professionalised work is closer to those that collaborate in other tasks and publications and are supervised in the manner described above. Exclusive dedication to the doctoral thesis occurs, therefore, in conjunction with other types of supervision, chiefly in relation to research work rather than daily tasks.

Graph 1: Principal Components Analysis with postgraduates (category co-ordinates)

The procedure used here allows us to derive a map of the distinct training styles or modes by defining relatively homogeneous practices. The next step in the analysis is to classify the respondents into two groups by means of a cluster analysis that represents 37.4% and 62.6% of the sample and which are reflected in Model I and II above. By examining the scores at the nucleus of the clusters, we see that cluster 1 is composed of those with a negative score in dimension 1 and a positive score in dimension 2. Cluster 2 is composed of those with opposite values to the above. Thus the group that performs classic academic work includes those respondents who work exclusively on their thesis, while the professionalised group spends more time conducting scientific work at the centre. The two groups are interpreted as a reflection of two distinct approaches: the scientific worker and the scientific apprentice which is considered below.

Table 2: Postgraduate training models by discipline and type of centre

When the resulting two groups are crossed with 'type of centre' and 'discipline', significant differences can be seen which support the above observations, demonstrating that this operation is useful in classifying the current training system in quantifiable terms. The distribution of the cases in both clusters for each type of centre and discipline shown in Table 2 indicate the following: i) post-graduates in natural and technological disciplines receive more professional training than those in the humanities or social sciences, and ii) training practices in universities are less professionalised than in public research centres. This confirms that, in fact, there does exist a logical set of activities that characterise two differentiated training styles and which differ by discipline and type of centre.

The qualitative data selected clearly illustrates the previous results.[11] The practices described above are directly related to the comments made by the grant holders themselves on the rôle that they play in research centres or university departments and have chiefly to do with their situation within the research field in accordance with the two extremes of 'scientific worker' and 'postgraduate student.' In the natural disciplines, where experimental research is more common, the situation of the grantees is far removed than that of the students, including that of graduate students, and is viewed by the subjects themselves as a professional activity. The following comment by a grant recipient in biology clearly reflects this trend:

> [G1] ...In our case, from the moment we begin to work we feel like professionals, not students....You begin with work that you carry out until a given moment, when you reach a milestone as in any other job. That's when you read your thesis and then that's it, the work carries on in much the same way...

The doctoral thesis also presents significant differences in terms of how it is conceived and how results are assessed:

> [G1]...There is no well-defined line when doing a thesis. You plan it as you go since you find things that might be more interesting, but there is never an objective. I mean, there isn't a complete body of work. You reach certain conclusions from which you can formulate models. There is a point at which you accumulate a certain amount of results that are more or less coherent and then you stop and write your thesis. This is usually because your grant runs out.

These comments are a true indicator that in the experimental sciences, although the thesis is a clear objective and a necessary credential to continue on in the scientific profession, training practices are restricted, to a large degree, to participating in research projects which will produce the necessary results to do a doctoral thesis. In contrast, in the social sciences and humanities the thesis is seen as an end unto itself, and work is aimed at organising a body of knowledge and empirical evidence that will produce a final result. Thus the typical case of a doctoral candidate who does a thesis in the social and human sciences, and in many cases in the non-experimental natural sciences as well, is one of a student that carries out his work independently and reports to the advisor at periodical intervals. For these doctoral candidates, association with a centre is a means of gaining access to resources and facilitating the sporadic exchange of experiences and know-how with other members of the profession.

The following point made by a grant recipient in economics describes this process:

> [G2]... Basically, I work alone. What I can do at the department, I could do at home, but it's easier for me to work here. Not only because there is a library and a computer, but because there is a working atmosphere...If that weren't the case, I would be doing the same thing I did as an undergraduate, except that I'd have a concrete objective, which is to finish my thesis...You could say we are professional students, because we are being paid to study and because you have to produce some results...

This wide range of situations has brought about notable differences in the strategies used to train researchers, derived from the degree of association with the centre and the relationship with advisors which, in turn, has largely to do with whether work is carried out in a group setting or not. At the far extreme we find groups where the thesis is only one part of a common research project and the young researcher is one member amongst many of a team. In this case, different theses which are supervised in the same group are, more often than not, simply different approaches to the same problem. At the other extreme, research training is up to the individual, that is, the doctoral thesis is independent from the work of the supervisor and the research group and no two theses are alike.

In sum, the practice of science in academia by new research trainees is structured around the following components: the type of scientific discipline practised, the type of institution where research is done, and the internal organisation of the research work. This last factor is especially relevant when research is conducted in groups and specialised technical resources are available, since this will determine how the work of a doctoral candidate is organised in terms of supervision and tasks. Let us now consider this question from the viewpoint of faculty strategies.

Training people in academia: faculty strategies.

Similar procedures were followed for the sample population of researchers. A group of variables was chosen to reflect the procedures used in supervising post-graduates. Here, in addition to examining the way advisors supervise, we have examined the criteria followed by them when directing doctoral theses. While some supervisors will only direct theses by candidates with a grant, others do not require candidates to have a grant. This variable sums up the criteria of professionalism in the scientific world since a grant means that candidates must dedicate their time exclusively to their research and are assigned specific duties at their workplace. Our study also includes supervisors criteria on how the thesis topic is chosen. Two extremes have been observed: supervisors establish the topic according to their own line of work and offer few alternatives to the doctoral candidate, or they allow candidates to choose their own topic.

The descriptive results are shown in Table 3. 76.2% of those interviewed have directed theses without grants[12], 44.7% solely or principally direct candidates with a grant and 24.1% establish the topics that they are willing to direct beforehand. Additionally, 69.7% supervise by means of periodical reports, 51.6% require that results be presented publicly and 58.3% require publications. 39.9% do not require that candidates work at the centre.

Table 3: Training strategies used by supervisors

The data reduction analysis empirically confirms in quantitative terms the two types mentioned above. Using the variables given, the results are grouped into a pattern which shows a logical interrelation between more formal and less formal aspects of scientific research training as shown in Table 2. Thus, for the two dimensions, the first includes the variables that refer to the learning process and is interpreted as ‘collective vs. individual organisation of science,’ meaning that when a scientific apprentice decides to embark upon a career in the sciences, the capacity to make decisions and act autonomously are relegated to the demands of everyday practice. The second dimension can be interpreted as ‘the autonomous approach vs. the integrated approach’ and is principally differentiated by the type of supervision undertaken.

Graph 2: Principal Components Analysis with supervisors (category co-ordinates)

Table 4: Supervisor training models by discipline and type of centre

Table 5: Component loadings

Closer supervision implies a greater demand for post-graduates to dedicate their time exclusively to a specific project and less freedom to choose a research topic. Classification into two types corresponds to the two different training styles observed in the study: a formal and informal model. The sample is divided into two groups according to the scores obtained in the reduction of dimensions, together with distribution by place and discipline. Table 4, where Model 1 predominates, shows the results of the cluster analysis. In contrast, Model 2 is found more frequently in the natural fields and in the CSIC institutes. Model 2 includes 22.2% of scientific researchers at universities and 50.5% of the scientific researchers who work at the CSIC, thus confirming the above hypothesis. Nonetheless, it should be stressed that this contrasts with the day-to-day reality experienced by post-graduates. While the majority of post-graduates are trained according to a professional-type model, most researchers are trained by more traditional methods. This is a direct consequence of the fact that not all members of the Spanish scientific community participate equally in grant policy. The majority of grants are supervised by a small group of researchers who are closer to a professional model and at the same time are more active in research in all types of centres and disciplines.[13]

This distinction clearly reflects the fact that in the social sciences and humanities, and in those techno-scientific areas which are less experimental and more theoretical in practice, doctoral research is conceived of as a much more individualistic undertaking. In the laboratory disciplines, however, research work is considered to be a collective task. The comments made by the researchers themselves during the in-depth interviews underline this point.

With regard to the choice of research topic, for example, a polarisation of the two types of disciplines can be seen. In the more individualistic disciplines, where research is deemed to be a highly personal process, researchers are deeply committed to their work and the best way to ensure this is to allow the researchers themselves to choose their research topic. This does not mean, however, that supervisors play a passive rôle, since recent graduates are not well versed enough to decide which aspects of their field are original and likely to produce relevant findings. Nonetheless, once a theme is determined by the student or suggested by someone with more expertise, the direction and supervision occurs later, although the student's own initiative does play a decisive rôle in the initial choice.

Quite the contrary occurs in the experimental sciences where the choice of a research theme is determined by the work of a researcher or group. Typically, once a student is selected to participate in a programme, it is the supervisor who decides the research topic. The choice is then discussed with the group director and the new member is assigned to a specific task. Thus, in these disciplines, the thesis question to be investigated during training is usually not chosen by the candidate. Instead, the doctoral candidate begins to work on seeking solutions to specific questions. This does not mean, however, that there is no room for discussion or negotiation, but usually the degree of specialisation inherent to the scientific and technical disciplines offers few possibilities for a beginner to develop an idea or hypothesis which is relevant to the group as a whole, especially when a large number of resources are needed to conduct research. On the other hand, doctoral theses in the social sciences and humanities usually adhere to a different rationale than that of the natural sciences. In the former, efforts are chiefly focused on methodology and the discussion of results with less importance given to the question itself, while in the former, achieving results which will contribute to resolving a problem, as minor as these may be, takes priority and doctoral theses are often the result of several pieces or parts of the research conducted.

This difference lies not only in the organisational features of the research objective itself, but also the different way in which scientific disciplines are developed. For example, the different areas of physics, chemistry or biology are found in myriad places and the degree of specialisation is such that great effort is needed to produce even a small amount of research and researchers must ensure that the research is scientifically significant by investigating prior work which, in turn, may be valid for only a short period of time. In addition to being highly specialised in a given area of problems, the researcher must be skilled in the use of techniques or sophisticated equipment, meaning that a specialist will not run the risk of working in an area in which he has no expertise. A researcher in biotechnology expresses it this way:

> [I1] ...I would never venture to direct a thesis on something in which I am not an expert, simply because it would not be honest of me. If I decided to back and direct an experiment into something which I had not worked on in depth, it is likely that someone somewhere else had already done it better long before. I would therefore be

> misleading the person who has to invest his time. In fact, this already happens with the things in which we are specialists, because competition is fierce in biotechnology.

In other disciplines, however, research topics are negotiable and the doctoral candidate has greater freedom to decide because the knowledge obtained is not as cumulative and it is not absolutely necessary to be as specialised in a given topic. Many disciplines rely upon a common corpus of knowledge that can be applied to a variety of research objectives. The following opinion of a philologist sheds some light on this question:

> [I6] You can always direct a thesis on a related topic, because the most important thing is to know how to find your sources, to use the correct methodology and to expound your ideas well and write skilfully. You don't need to be a specialist to do that. That isn't to say that because you are a professor of philology you can direct everything in this field, but since the main effort must be made by the doctoral candidate himself, it is enough to be supervised by someone with a certain amount of experience.

In much the same way as topics are chosen, the decision as to how research should be done and the way in which doctoral candidates are assigned to research is very different in the experimental sciences where lab work is conducted with regard to fields where it is not. It could be argued that training is structured around the nature of the work, namely, where it is done, what equipment is available, and how the candidate is incorporated into teams of specialists. Hence, the technical features of the different disciplines correspond to distinct training practices in terms of time spent, the relationship between supervisors and postgraduates and the rôle played by the latter in research groups.

From the interviews and qualitative studies carried out here, two typical research training schemes have emerged. One is an autonomous system based on a series of programmed activities where post-graduates are located at the bottom rung of the occupational ladder of science,[14] while the other is integrated into the daily practices of the workplace. In general terms, this is similar to what we discussed above insofar as research post-graduates are divided into two opposing categories: 'professional students' and 'scientific workers.'

Based on the responses by the supervisors, the first training scheme has been called 'training based on programmed activities,' since the nature of certain disciplines allows us to split the work of the doctoral candidates from other kinds of work and establish individualised training schemes. This is usually true of work groups in the same institution who practice the same discipline, but whose research is chiefly individual. Thus, training is often organised around an experienced researcher and, more often than not, training is restricted to the individual interactions between the supervisor and post-graduate student and contact with other members of the academic community are usually channelled through the former. Training normally involves reading the available literature and is viewed as a time to become acquainted with the question at hand after which the thesis topic is chosen. It may also include contacting other qualified researchers or periodical consultations with the supervisor.

In this model, doctoral theses which are undertaken within an academic department, or even by the same researcher, are independent in practice and can be carried out with a fair amount of autonomy by the doctoral candidate. Contact with the supervisor does not occur on a daily basis and the work is not directed all of the time although the advisor is responsible for designing the research program and supervising the work once it is underway. To this it should be added that the work can be done outside the institution since there is no special need for space or technical resources, or simply because the necessary resources are available elsewhere. Supervision occurs at specific moments or intervals during training and usually consists of little more than draft revisions. The following comment by a geography professor describes a typical supervision scheme :

> [I7] ...the post-grads under my supervision are quite independent, which doesn't mean that they can just forget about everything. When a reasonable length of time has passed and I've heard nothing about the results of their work, I speak to them and ask for an explanation if necessary. Their work involves a series of medium-term tasks which do not require daily supervision.

While it is difficult for supervisors to evaluate the responsibilities involved in their work, most state that they do set time aside for discussion or to revise written work. The rôle of the post-graduate is not perceived as being fundamental to the core research in that it is not vital to the production of new knowledge. The final objectives of training lie in the individual accomplishments of the doctoral candidates which take the form of a thesis or publications; either individual or in collaboration with the supervisor. The responsibility of the advisors, therefore, is to provide supervision to ensure the professional development of the person. A professor of law comments upon the advantages of individual work:

> [I8] They are people who to some extent are under my supervision, and for whom I am somewhat responsible, but they are completely autonomous and work on their own...Each one must worry about his/her own life project...just as I have my own. But my rôle is, in part, to help bring that project to a successful end so that they may then continue on their own.

The second model mentioned above is that of 'integrated training.' This model is notably different in that it is structured around the working teams commonly found in the experimental sciences and where a specialised set of tools and mechanisms are needed to acquire new knowledge. In this type of setting, the doctoral thesis tends to be a subproject of a larger research project and theses are integrated into a line of work which is already underway, allowing the candidates to make use of the available technology and accumulated knowledge on a particular research problem.

Training here does not involve individualised programs that can be carried out independently. On the contrary, there is daily contact and interaction with the supervisor or other members of the laboratory who need help on a day-to-day basis. In this case, supervision depends on the requirements of the experimental work itself. More than a program of activities carried out autonomously, there is usually a working plan with specific short-term objectives which require the collaboration and participation of other members to prepare materials and run equipment.

It is much more difficult in this case for the doctoral candidates to conduct their work freely. Doctoral theses make up only a small part of the total work conducted in the laboratory and completion of a thesis depends upon the results obtained. Thus, as a chemical researcher observes, it is more difficult to define the activities carried out by doctoral candidates:

> [I3]...in this laboratory, writing a thesis is just one of many activities. When you start out there are many things going on at once, then one thing begins to stand out and takes priority over the rest. Your relationship with your colleagues is a very close one and you learn from them everyday.

Experimental scientists are rarely able to differentiate between time specifically spent on training and time devoted to research. In short, research and training are practically one and the same and training is just one of many tasks undertaken during research. As the following comment by a research biologist shows, it would be impossible to distinguish training from what goes on in a normal working day:

> [I2] In our area, the training of post-graduates in science runs parallel and is indistinguishable from the research work itself. It is no different...I wouldn't be able to make a distinction between what is normal work and what is training...perhaps it can be summed up every so often when there is a group seminar..., but that is something which takes up very little of our time.

Discussion

Thus far we have discussed the quantifiable dimensions and some of the issues that explain, in part, the various schemes and factors which determine how scientists are trained in academia. While some of these factors appear to be related to the immediate context of disciplines and centres, the different training styles observed here are only one of the components which reflect the broader trend of change occurring in traditional scientific institutions.

The practices described herein coincide, to a large degree, with the typical training models employed in the social sciences and humanities, as well as in experimental sciences in a laboratory setting, albeit with notable differences in terms of the rôles and responsibilities of supervisors. This division coincides to some extent with the classic idea of the two cultures [Snow, 1960] which established a difference, in cognitive and organisational terms, between literary and scientific intellectuals. However, although the two models set forth by Snow may coincide in a general way with the current experimental scientific disciplines and the social sciences and humanities, in reality this division is not the sole consequence of this difference. What we see here are two very distinct ways of shaping one of the social processes of science: the reproduction of scientific groups according to the characteristics of work rather than interdisciplinary differences, due to the organisational complexity inherent to the 'collectivization' of scientific disciplines [Ziman, 1983].

First, there exists a collective control which is external to science by means of a science policy which demands profitability in order to finance research infrastructures. Thus the freedom of academics to choose research is restricted by the demands imposed by science funding bodies and it is logical that in those places which are more subject to external pressure, the freedom to choose is more restricted. Second, the internal characteristics of science constitute another element of change, namely the components of the technical and organisational apparatus that surrounds research. To undertake a scientifically significant task, sophisticated instruments and equipment are needed which must be quickly replaced and renewed and can only be handled by highly qualified personnel. What is more, the raw materials and infrastructures needed to conduct research are costly, meaning that for research to be done, equipment and facilities, which are only available in a small number of institutions, must be shared. Hence, teamwork is inherent to collective science because of the need to share resources and specialised workers alike.

The different training schemes described here mirror a change that is taking place in the organisation of science in certain institutions. The figure of the scientific trainee immersed in collective science is, generally speaking, that of a person who must select a topic which is relevant to the scientist and which will justify being included in a research group, while the research must likewise justify cost to the organisation in terms of resources. The young scientist must adapt to the requirements imposed by the research and co-ordinate his or her work with that of other members of the team, meaning that research must be done in a specific place and go according to plan. And last but not least, research must be useful if the institution and the researcher are to invest both their time and money. Consequently, the personal autonomy of novice researchers is curbed: they are not free to choose their area of research, work at their own pace or combine work on other tasks as they have restricted access to the resources needed to do research.

The fact that a scientific career is determined or not by the requirements of collective science clearly responds to the need to develop science with this type of internal organisation. Basically, this occurs in those branches of science which, because of their evolution, level of specialisation and sophistication and high cost of resources, are forced to make use of this type of social organisation, as the ‘laboratory’ sciences would confirm. Nonetheless, although the features outlined here are more frequently found in these fields of science, they can also transcend the boundaries of disciplines to include certain fields in the social sciences and humanities that would normally be considered individualistic.

For example, there are some specialities in the social sciences, such as sociology or economics where work is structured around research groups similar to those found in scientific-natural disciplines and which make use of equally complex mechanisms for the production of data, implying the need for facilities and high level of funding. In other humanistic disciplines, such as archaeology, research is done *in situ* and normally requires the use of sophisticated techniques to analyse and catalogue materials. Although the situation *is* changing in many disciplines where research material once consisted of little more than a pencil, pen and paper, we must not overlook the fact that still today in some areas of the natural sciences or technologies, especially in universities, experimental research is simply not done and there are numerous departments which use an essentially didactic approach because they receive no funding for empirical research. In sum, the ways of training largely depends on just how formalised scientific activity is within a given institution or research group, the ability to adapt specific practices to work objectives and whether research is an individual or a team task (depending, of course, on whether special equipment or resources are available to the individual researcher) The most important issue to keep in mind when defining training practices, then, is the rôle that research plays within an institution and how it is organised.

The aim of this empirical study has been to throw some light on the rôle of these two scientific training models in Spanish institutions. Approximately a third of the pre-doctoral graduate students in academia are closer to the figure of 'professional student,' while the majority correspond more closely to the model of 'scientific worker.' Whereas the former are found chiefly in the field of social sciences in the universities, the latter are present in the exact, natural and techno-sciences at public research centres. This distribution is indicative of the rapid process of change that is taking place in academic science in Spain and reflects the fact that, although national policies for the funding of research are not the only access route to the sciences in Spain or the sole way to train scientists, it is certainly becoming the predominant one. Consequently, it is precisely because of this science policy and the strategies of academic workers that are more active in 'capturing' human and other resources, that grant funding now responds more to the requirements and criteria of this new organisational mode of science.

Although the training systems examined here continue to be essentially academic in terms of their research practices and professional orientation, this is certainly not so in terms of the philosophy underlying certain practices in training policy, including greater planning of human resource training, the concentration of training in settings or groups which are more active in research, the use of new management tools, and control mechanisms implemented through science policy. All of these factors mean that today the majority of new scientists are trained in a distinct context from that of classic academic science. It could be argued, then, that the relationship between the way in which a large part of the Spanish R&D system functions and the way science is organised is, to say the least, a strained one. This is chiefly the result of the different training strategies used by supervisors, departments and research centres, contributing to a greater stratification of the Spanish scientific community. Likewise, a gap now exists between the new generation of scientists who are trained in an organised scientific setting and senior scientists who are stuck in traditional science practices and are consequently removed from the current reality of scientific activity.

Notes

The quantitative base used for this study was funded by the Spanish Interministerial Committee of Science and Technology (CICYT) through a project of the National R&D Plan. I would like to express my thanks to the heads of the project, Dr. Manuel Pérez-Yruela and Dr. Teresa González-De la Fe. I am also grateful to Dr. Cristóbal Torres for conducting some of the interviews and group discussions and to Begoña Buiza for the statistical assessment.

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1. For other studies of the social changes occurring in the organisation of science see Gibbons, et al. (1994), Cozzens et al. (1991) and Ziman (1996).

2. The concept of paradigm is understood as the set of assumptions and procedures in the management of scientific research which are commonly used over a given period of time. The

ideas of Elzinga and Jamison (1996) and Ruivo (1994) have been used for paradigms in science policy. For a more general use of the concept for public policy see Hall (1993).

3. To initially formulate this idea we have used the work of Prof. Ziman (1990; 1987b). Similar approaches on the transformation of scientific training can be seen in studies that examine the current state of national R&D systems with regard to the training of scientists and academics (Blume, 1995; Clark, 1995).

4. 25% of the total funding provided under National R&D Plans in Spain from 1985-1995 was aimed at research training. During that period of time a total of 12,000 pre-doctoral grants were awarded. See CICYT (1992; 1995).

5. Until the 1980s Spanish science was clearly in a state of underdevelopment in comparison to other OECD countries. In 1980, for example, scientific production in Spain made up 0.8% of the total production in international data bases. Investments in R&D amounted to approximately 0.4% of the GDP, lower than what should correspond to the economic development of the country (INE, 1991; CICYT, 1994). Scientific productivity was rarely a criteria when distributing awards or promoting careers in Spanish universities. See Nieto (1984).

6. The training programs established under the National R&D Plan consist of pre-doctoral research grants for a period of 4 years. These include a yearly stipend and financial support to undertake research in a department or research centre based on a specific project, under the supervision of a tenured faculty member or researcher. Pre-doctoral training in association

with companies and post-doctoral training are also available, although less common. See CICYT (1995; 2000).

7. The research project was financed by the National R&D Plan in 1997 and carried out in the Institute for Social Studies in Southern Spain (IESA) of the CSIC. The project's technical features are included in IESA (1998). For evaluative findings of the study see Fernández-Esquinas (2002).

8. The survey was conducted by mail in 1998 using strata according to type of institution for training and scientific field following UNESCO guidelines. The sample is representative of National R&D Plan grant recipients in the public sector with a margin of error of –2.5% and a confidence level of 2 sigmas. Four group discussion sessions were conducted with post-graduates from different disciplines and fields of knowledge.

9. The survey, conducted by mail in 1998, included 2,656 university professors and CSIC researchers. Only those respondents with experience in training researchers have been included in the analysis. The survey was conducted using professional category strata and scientific fields according to UNESCO guidelines. The whole sample is representative of the Spanish scientific community in universities and public institutions with a margin of error of +-1.6% and a confidence level of 2 sigmas. Additionally, twelve in-depth interviews were carried out with professors and researchers from various scientific fields with experience in supervising post graduate students.

[10] Principal Component Analysis for Non-Linear Data (PRINCALS) implemented in SPSS for Windows (V.7.5) was the data reduction technique used for both samples. See Afifi and

Clark (1997), Gifi (1990) and Michaidilis (1996). Clustering procedure was K-average Cluster Analysis. See Romesburg (1984).

11. In the transcriptions of the comments [G] refers to group and [I] refers to interview.
-Discussion Groups: [G1]: Post-graduates in biology at the Universidad Autónoma of Madrid and the CSIC. [G2]: Post-graduates in Social Sciences at the Universidad de Madrid.
-Interviews: [I1]: Biotechnology Researcher, Universidad Politécnica de Madrid. [I2]: Biology Researcher, CSIC. [I3] Chemical Researcher, CSIC. [I6]: Professor of Philology, Universidad de Alcalá. [I7] Professor of Geography, Universidad de Córdoba. [I8] Professor of Law, Universidad de Madrid.

12. It should be stressed that the initial survey was based on a representative sample of Spanish professors and researchers (n=2656), 59% of whom had no experience supervising. The subsample used here is of researchers with experience supervising post-graduates (n=1575).

13. 25% of Spanish researchers supervise 60% of the grants financed under the National R&D Plan. Likewise, participation in training policy is directly correlated to the amount of time spent on research and the funding received for research projects. For more on this point see Fernández-Esquinas (2002).

14. In Spanish scientific institutions, mainly the CSIC and university departments which are more actively involved in research, a great deal of the scientific work is sustained by grants awarded to post-graduates in a variety of fields. In the Spanish R&D system, a large part of

the research work, about 20%, has been and continues to be done by the grant recipients themselves. (INE, 1991; 2000).

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Table 1: Training features of postgraduates

Variable	Category	%
Main tasks performed during grant period	Thesis only	47.7
	Participation in project aimed at completing thesis	47.2
	Participation in project, not aimed at completing thesis	0.8
	Acquisition of speciality	2.8
	Other	1.4
	Total	100.0
Collaboration in research projects not related to thesis	Never	34.0
	Sometimes	49.4
	Often	10.7
	Very often	5.8
	Total	100.0
Collaboration with supervisor in publications	Never	44.5
	Sometimes	41.8
	Often	8.9
	Very often	4.8
	Total	100.0
Teaching duties	Yes	46.9
	No	53.1
	Total	100.0
Publication-based supervision	Yes	43.4
	No	56.6
	Total	100.0
Amount of time spent at workplace	< 50%	16.7
	51-70%	9.8
	71-90%	41.4
	>90%	32.1
N=1268	**Total**	100.0

Table 2: Postgraduate training models by discipline and type of centre.

	Cluster Type		
Discipline and type of centre (%)	**Model I**	**Model II**	**Total**
University – Natural and Technical Sciences	38.8	61.2	100.0
University – Social Sciences and Humanities	45.7	54.3	100.0
CSIC – Natural and Technical Sciences	17.6	82.4	100.0
CSIC – Social Sciences and Humanities	40.9	59.1	100.0
Total	37.4	62.6	100.0
No. of cases	479	789	1268
Nucleus of final clusters			
Dimension 1	-0.72	0.43	
Dimension 2	0.76	-0.46	

Table 3: Training strategies used by supervisors

Variable	Category	%
Doctoral candidates supervised without grants	Yes	76.2
	No	23.8
	Total	100.0
Supervisors requirements for directing a thesis	Only for grant recipients	13.4
	Post-grads without grant only on exception	31.6
	Not important	57.0
	Total	100.0
How research topics are chosen for thesis	Pre-established topic	24.1
	Topic negotiated	67.9
	By choice of doctoral candidate	8.0
	Total	100.0
Supervision through timetable at workplace	None	19.7
	Some	40.4
	Frequent	39.9
	Total	100.0
Supervision through periodical reports	None	6.2
	Some	24.1
	Frequent	69.7
	Total	100.0
Supervision through public presentation of results	None	9.3
	Some	39.1
	Frequent	51.6
	Total	100.0
Supervision through publications	None	7.4
	Some	34.2
	Frequent	58.3
n=1575	**Total**	100.0

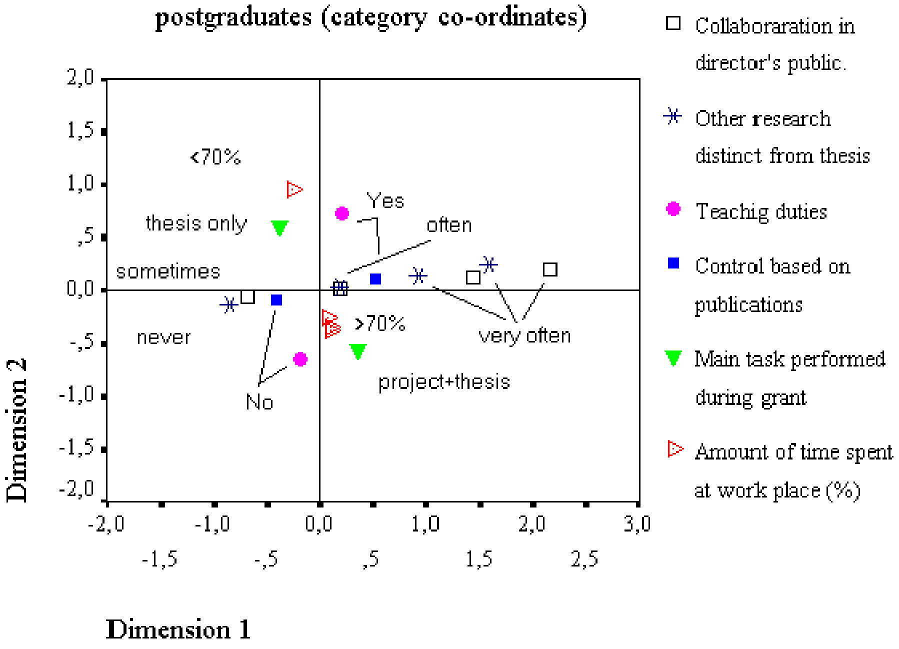
Table 4: Supervisor training models by discipline and type of centre.

	Cluster Type		
Discipline and type of centre (%)	**Model I**	**Model II**	**Total**
University – Natural and Technical Sciences	77.8	22.2	100.0
University – Social Sciences and Humanities	91.6	8.4	100.0
CSIC – Natural and Technical Sciences	49.5	50.5	100.0
CSIC – Social Sciences and Humanities	77.8	22.2	100.0
Total	73.7	26.3	100.0
No. of cases	1160	415	1575
Nucleus of final clusters			
Dimension 1	-.33	.91	
Dimension 2	.41	-1.33	

Table 5: Component loadings

Variables	Dimension 1	Dimension 2
- Sample: post-graduates		
Main task performed during grant	.370	-.585
Collaboration in other research distinct from thesis	.076	.108
Collaboration in publications by the director	.790	.070
Teaching duties	-.192	-.685
Supervision based on publications	-.460	-.098
Amount of time spent at workplace	.161	-.572
Eigenvalues	.3554	.2941
- Sample: Supervisors		
Existence of doctoral candidates without grant	.512	-.596
Requirements for directing a thesis	-.674	.465
How research topics are chosen for thesis	-.546	.133
Supervision through timetable at workplace	.248	.036
Supervision through periodical reports	-.156	-.004
Supervision through the public presentation of results	.506	.664
Supervision through publications	.593	.583
Eigenvalues	.4438	.2959

Graph 1: Principal Components Analysis with postgraduates (category co-ordinates)



Graph 2: Principal Components Analysis
with supervisors (category co-ordinates)